PRECISION COMPOSITE OPTICAL ELEMENTS

PAUL B. WILLIS
JET PROPULS ION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
4800 Oak Grove Drive, Pasadena, CA 91109
(818) 354-6998 paul.b.willis@jpl.nasa.gov

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MLS MISSION
(MICROWAVE LIMB SOUNDER)

- **SATELLITE:**
  FUNDED BY GODDARD; PART OF THE EARTH OBSERVING SYSTEMS (EOS) "CHEM" PLATFORM, BUILT BY TRW, FOR LAUNCH IN 2002. SUCCESSOR TO THE UPPER ATMOSPHERE REASEARCH SATELITE (UARS)
- **SCIENCE GOALS:**
  ACQUIRE AND ANALYZE MICROWAVE SIGNALS FROM EARTH'S ATOMSPHERE. DETERMINE: (a) IS THE OZONE HOLE RECOVERING, (b) HOW DO KEY GASSES MIX, AND, (c) DETECT CHANGES IN OVERALL CLIMATE OF THE EARTH
- **MEASUREMENTS:**
  MICROWAVES EMITED BY WATER VAPOR, OZONE, CHLORINE OXIDES, NITROGEN OXIDES AND OTHER KEY GASSES

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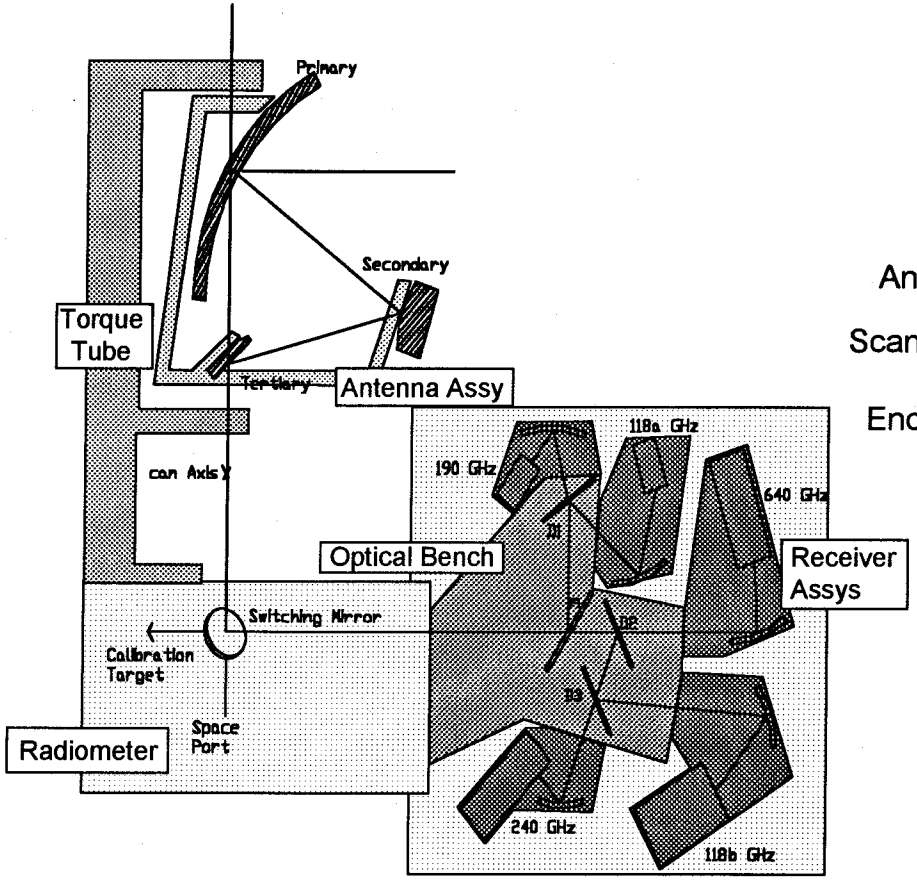
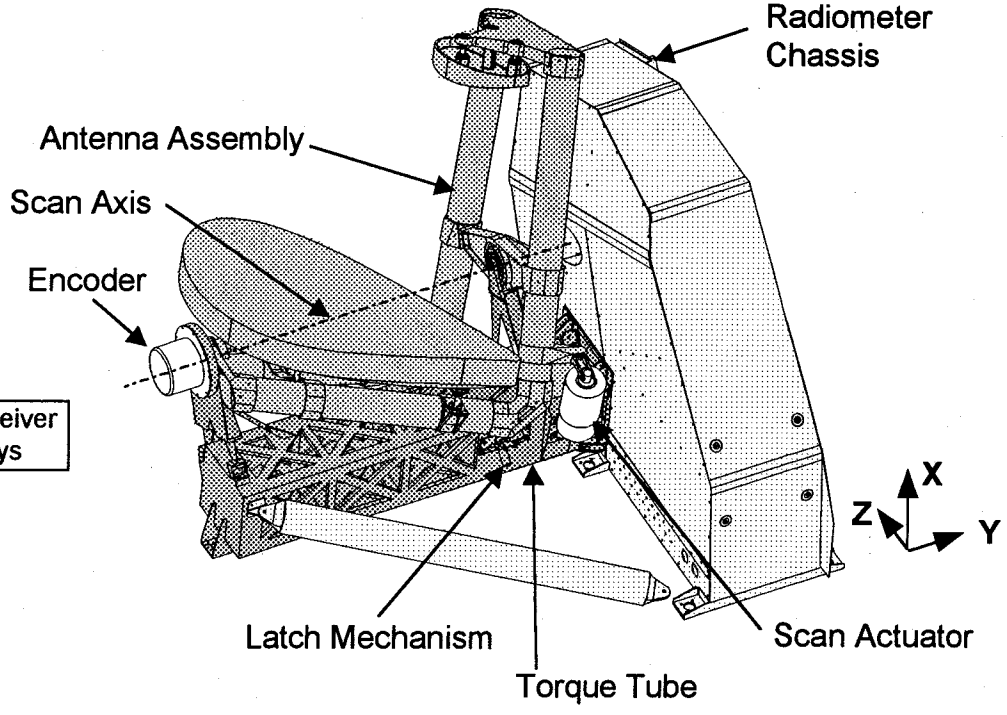
MLS INSTRUMENT

- **MODULES:**
  GIGAHERTZ, TERAHERTZ (WATER), & SPECTROMETER
- **GIGAHERTZ MODULE:**
  CONSISTS OF ANTENNA AND RADIOMETER. THE ANTENNA IS A THREE REFLECTOR CLEAR-APERTURE OFFSET CASSEGRAIN SYSTEM THAT COLLECTS AND FOCUSES MICROWAVE RADIATION INTO THE RADIOMETER FOR ANALYSIS
- **RADIOMETER: DIRECTS THE SIGNALS TO DETECTORS CENTERED AT 118, 190, 240 AND 640 GHz; GENERATES INTERMEDIATE FREQUENCIES, AMPLIFY, DOWN-CONVERT, ANALYZE, SEND TO TELEMETRY**
- **SHORTEST WAVELENGTH (640 GHz) IS 470 MICRONS**

MLS INSTRUMENT





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MLS PRIMARY REFLECTOR REQUIREMENTS

- PRIMARY REFLECTOR IS THE HEART OF THE MICROWAVE COLLECTION SYSTEM
- DIMENSIONS: ELIPTICAL, 1.6 x 0.8 METERS
- SURFACE AREA: 1.005 SQUARE METERS
- MASS LIMIT: 10 Kg (Maximum)
- CONSTRUCTION: COMPOSITE FACESHEETS (REPRODUCED OFF CARBON MOLD) WITH ADHESIVELY BONDED COMPOSITE RIB STRUCTURE (COMPOSITE OPTICS, INC.)
- MATERIAL: COMPOSITE - HIGH MODULUS GRAPHITE FIBER (M55J) WITH CYANATE ESTER RESIN (954-3), 350°F CURE
- FIGURE ACCURACY REQUIRED: 8.5 MICRONS, RMS (LAMBDA OVER FIFTY)

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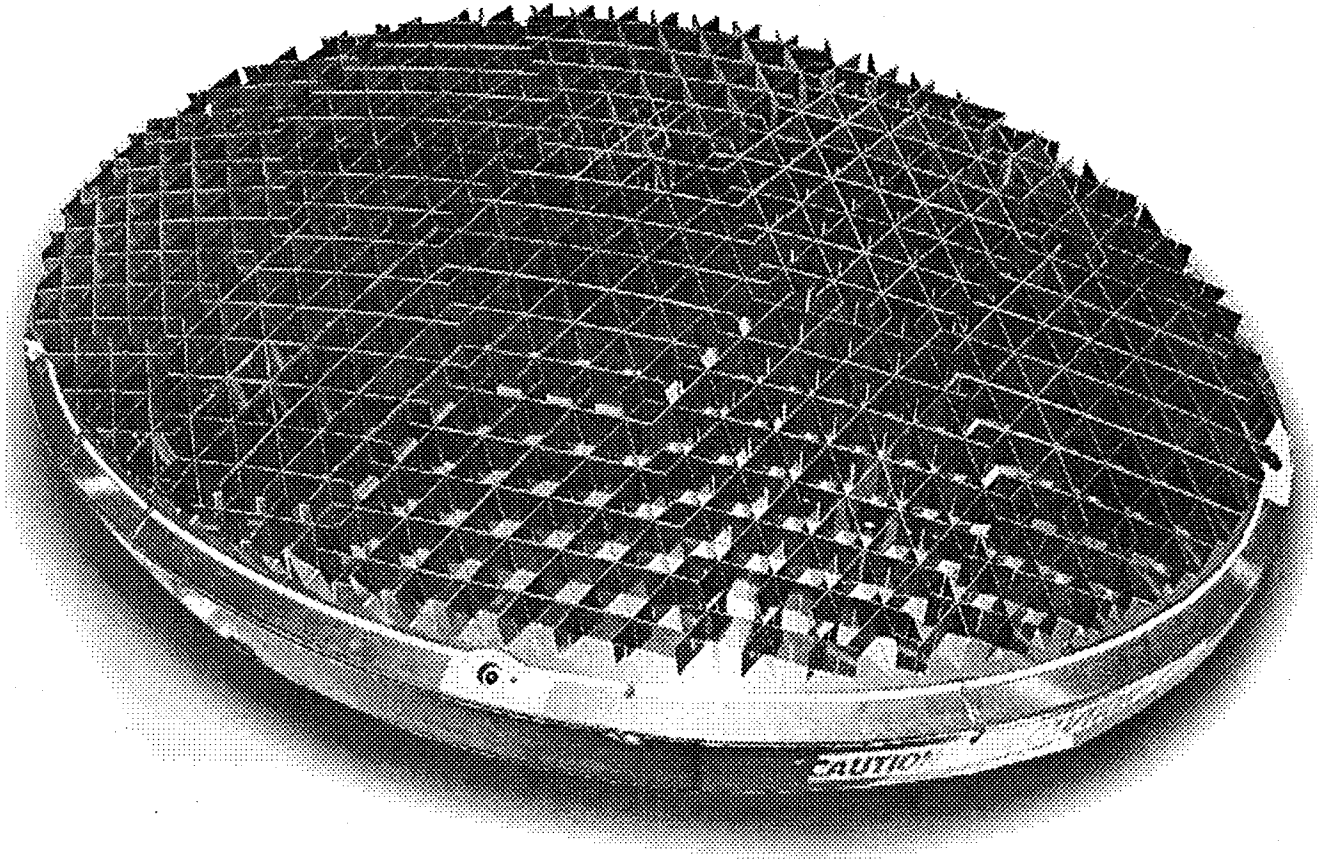
MLS PRIMARY REFLECTOR
MOLD AND CORE ASSEMBLY



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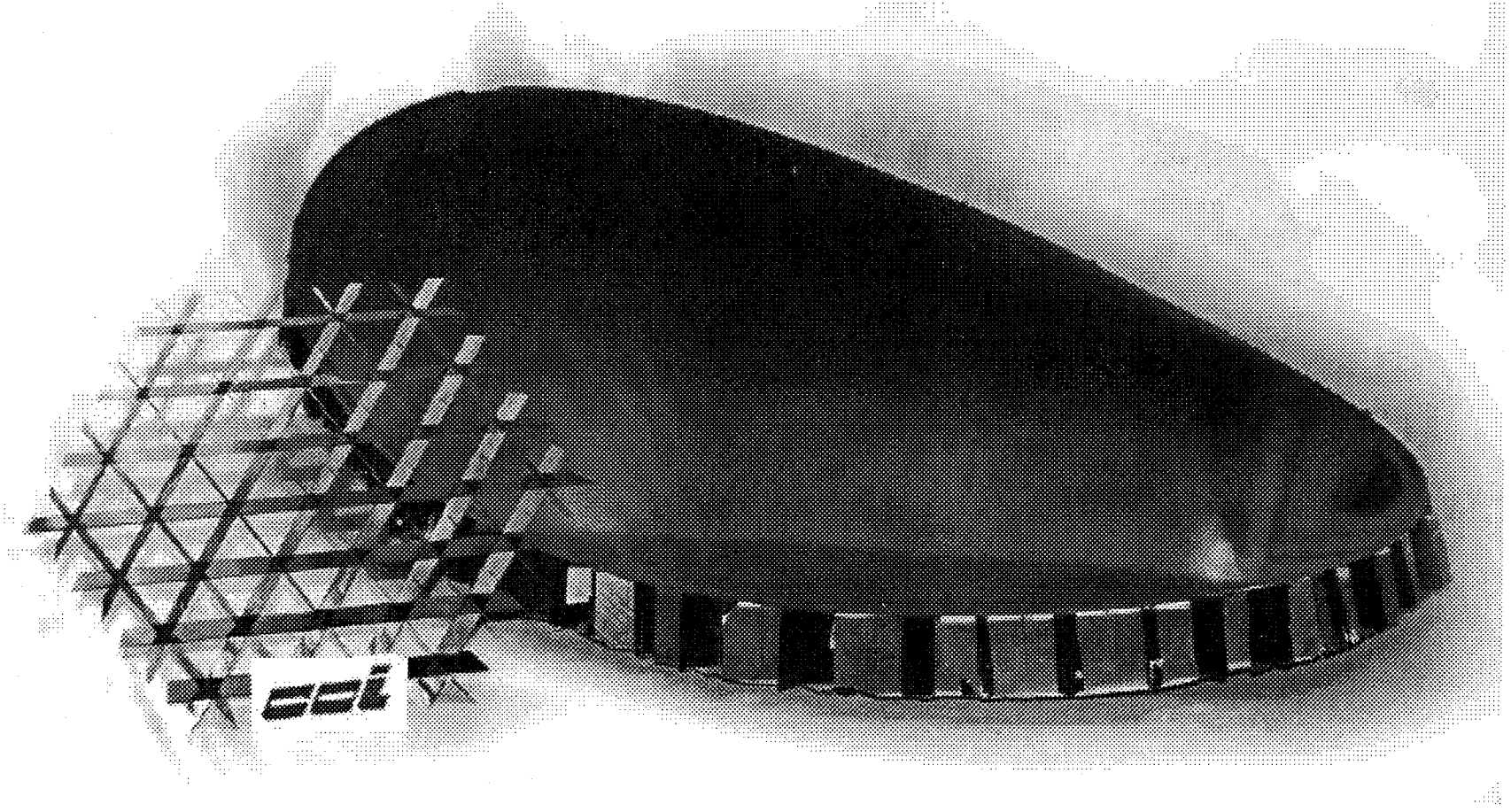
MLS PRIMARY REFLECTOR



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MLS PRIMARY REFLECTOR REQUIREMENTS

- **RF PERFORMANCE: REFLECTIVE FROM 118 TO 640 GHz, REQUIRES COATING WITH 1.2 MICRONS OF VAPOR DEPOSITED ALUMINUM ("VDA", FIVE SKIN DEPTHS) (SURFACE OPTICS CORP.)**
- **SPECULARITY: SOLAR, <10% AT 10° ANGLE OF CONE, TO PREVENT THERMAL LOADING OF SECONDARY AND OTHER REFLECTORS. ACCOMPLISHED BY PRECISION GRIT BLASTING OF THE SURFACE UNDER CNC CONTROL**
- **THERMAL BALANCE REQUIREMENTS:**
  ABSORPTANCE $=<$ 0.40
  ABSORPTANCE/EMITTANCE $1.0 < \alpha / \varepsilon < 2.0$
- **EMISSIVITY: ACHIEVED BY DEPOSITING AN 0.8 MICRON LAYER OF REACTIVELY FORMED SILICON SUBOXIDE (SiOx) (SURFACE OPTICS CORP.)**

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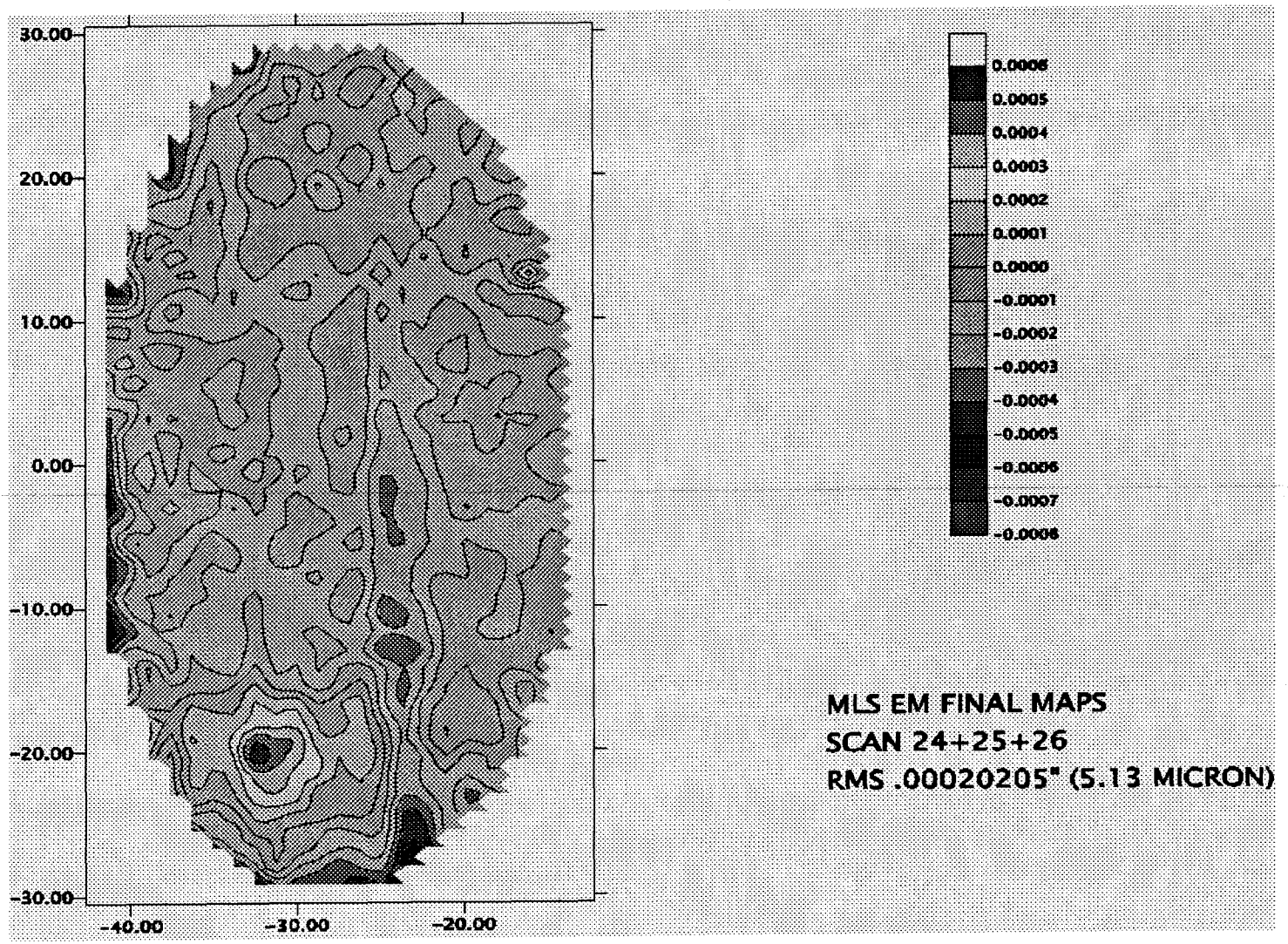
MLS PRIMARY REFLECTOR FIGURE MEASUREMENTS

- COORDINATE MEASUREMENT MACHINE: BROWN & SHARP - VALIDATOR 7236, PC-DMIS SOFTWARE, NEW ROTARY ENCODERS, OPERATED BY COMPOSITE OPTICS, INC.
- STATISTICAL ACCURACY: ESTIMATED AT 2.5 MICRONS OVER ENTIRE REFLECTOR AREA
- NUMBER OF POINTS: 1270
- NUMBER OF SCANS: THREE PER MEASUREMENT
- FINAL FIGURE: ROOT-SUM-SQUARE OF THE THREE RMS VALUES

MLS PRIMARY REFLECTOR

TYPICAL CMM FIGURE MEASUREMENT



MLS PRIMARY REFLECTOR FIGURE MEASUREMENTS

- **FIGURE MEASUREMENT SUMMARY:**

AS FABRICATED	**4.50 MICRONS, RMS**
AFTER THERMAL CYCLING (10 Cycles, -85°C to +90°C)	**4.39 MICRONS, RMS**
THERMAL VACUUM/ACOUSTIC (72 Hrs/+90°C, 143 dB 30 Hz to 10 KHz)	**4.45 MICRONS, RMS**
FOLLOWING GRIT BLASTING	**4.52 MICRONS, RMS**
FOLLOWING VDA COATING	**4.37 MICRONS, RMS**

- **PRIMARY REFLECTOR FIGURE APPEARS TO BE STABLE TO ALL PROCESSING CONDITIONS WITHIN THE ACCURACY OF THE CMM MACHINE**
- **MAJOR ERROR FEATURES ALSO MAP TO MOLD SURFACE. MOLD APPEARS TO BE THE LARGEST SOURCE OF ERROR**

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MLS PRIMARY REFLECTOR PERFORMANCE SUMMARY

PROPERTY	REQUIREMENT	ACTUAL
MASS	10 Kg	8.6 Kg
AREAL DENSITY	< 10 Kg/m^2	8.5 Kg/ m^2
STIFFNESS	80 Hz	288 Hz
FIGURE	8.5 Microns, rms	4.37 Microns, rms
ABSORPTANCE	=< 0.40	0.43
α / ε RATIO	$1.0 < \alpha / \varepsilon < 2.0$	1.30
SPECULARITY	<10% (10°angle)	7% (10°angle)

- CONCLUSIONS: VERY LARGE, HIGHLY ACCURATE AND LOW MASS REFLECTORS CAN BE FABRICATED USING COMPOSITES TECHNOLOGY

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COMPOSITE REFLECTORS FUTURE TRENDS

- **FIGURE OF MERIT:**
  APERTURE (m^2) / MASS (Kg) * FIGURE(μ rms) = TWICE THE VALUE OF THE NEW 8.1 m GEMINI REFLECTOR (HAWAII)
- **FIGURE ACCURACY:**
  ONE ORDER OF MAGNITUDE IMPROVEMENT REQUIRED FOR INFRARED PERFORMANCE (λ /10); TWO ORDERS OF MAGNITUDE IMPROVEMENT REQUIRED FOR VISIBLE
- **ERROR CORRECTION POSSIBILITIES:**
  IMPROVED MOLD SURFACES, MECHANICAL POLISHING, ION-BEAM FIGURING, EXCIMER LASER MACHINING, VAPOR DEPOSITION SMOOTHING; CORRECTIONS AT THE SECONDARY REFLECTOR
- **LARGE COMPOSITE REFLECTORS MAY EVENTUALLY (?) OPERATE IN THE VISIBLE REGIONS**